Comparison of Present Day and Historical Dispersal Patterns in the Western Adriatic

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LONG-TERM GOALS

By improving numerical representations of coastal circulation, sediment properties, and waves, we seek to develop reliable predictions of sediment concentration, transport and deposition. Calculations that simulate conditions during field experiments can be validated using observations. We can then extrapolate to longer timescales by running longer simulations, and by predicting dispersal patterns under configurations that represent past geologic or climatic conditions, when sediment and freshwater inputs would have been different. By using a well-tested model to evaluate the impact that such shifts in sediment and freshwater delivery have had on seafloor texture, we hope to bridge the gap between present day observations and the events and climatic shifts capable of leaving stratigraphic signals.

OBJECTIVES

Sediment delivery, flux, and deposition are quantified within a three-dimensional hydrodynamic model that links sediment transport in the western Adriatic Sea to deposition. The study focuses on evaluating sediment dispersal in the Adriatic under different wind regimes: the Bora winds are storm winds that blow from the northeast, and the Sirocco winds tend to be less energetic, but are directed up the axis of the Adriatic from the southeast. The largest point source of sediment within the Adriatic is the Po River, but dispersal in that region is poorly resolved in our current model (2-3 km resolution). This has motivated focus on the Po delta to use the model to evaluate competing hypothesis for sediment dispersal and delta progradation there.

APPROACH

Two systems have been considered. First, we study the modern Adriatic and continue to build a realistic simulation of the 2002 / 2003 study period. Our colleagues have a rich data set to classify both seafloor properties and water column sediment transport during this time, from the PASTA (Po and Apennine Sediment Transport and Accumulation) experiment. Secondly, a related study, reported last year, sought to quantify dispersal patterns of paleo-Po River sediment under conditions representative of the last glacial maximum (LGM), 18,000 years before present, when sea levels were 120 m lower.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2005**	2. REPORT TYPE	3. DATES COVERED **00-00-2005 to 00-00-2005**

4. TITLE AND SUBTITLE **Comparison of Present Day and Historical Dispersal Patterns in the Western Adriatic**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Virginia Institute of Marine Science,P.O. Box 1346,Gloucester Point,VA,23062**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
code 1 only

14. ABSTRACT
By improving numerical representations of coastal circulation, sediment properties, and waves, we seek to develop reliable predictions of sediment concentration, transport and deposition. Calculations that simulate conditions during field experiments can be validated using observations. We can then extrapolate to longer timescales by running longer simulations, and by predicting dispersal patterns under configurations that represent past geologic or climatic conditions, when sediment and freshwater inputs would have been different. By using a well-tested model to evaluate the impact that such shifts in sediment and freshwater delivery have had on seafloor texture, we hope to bridge the gap between present day observations and the events and climatic shifts capable of leaving stratigraphic signals.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**10**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

The Adriatic Sea is an excellent test bed for this effort because, for modern conditions, there is a rich data set available from the 2002/2003 EuroStrataform and ACE programs [*Lee et al.*, 2005] and hydrodynamic models have been implemented successfully for this time. Specification of winds and waves relies on ensemble models to specify non-uniform conditions in the Adriatic [see *Sherwood et al.*, 2004]. Winds are specified using predictions from two atmospheric models: the 4km-resolution Naval Research Laboratories COAMPS™ model (Coupled Ocean Atmospheric Mesoscale Prediction System); [see *Hodur*, 1997; *Hodur et al.*, 2001]; and the 7 km predictions of BoLAM (Bologna Limited Area Model; see http://www.cmirl.ge.infn.it/MAP/BOLAM/Bolamin.htm). Wave heights and periods are input from results of a SWAN model [see *Booij et al.*, 1999] run by Sherwood and Signell.

Sediment transport routines developed for ROMS allow input from fluvial sources and exchange between suspended and sea-floor sediment. Sediment is transported by settling, advective currents, and turbulent diffusion. Multiple grain types are used to track changes to seabed texture and differential transport of material. Sediment types distinguish between material delivered by the Po River, the Appennine Rivers, and resuspended from the seabed. This allows the model to evaluate which sources supply the various depocenters over seasonal timescales. Input of freshwater and sediment are difficult to prescribe, because within the study area only the Po, Pescara, and Biferno rivers are gauged. While previous studies provide some guidance for freshwater input [i.e. *Raicich*, 1996], and erosion potential [i.e. *Aquater*, 1982], these are monthly averages at best. We combined gauged and climatic data with sediment rating curves from Kettner and Syvitski [2005] and Syvitski and Kettner [2005] to specify freshwater and sediment inputs for 2002/2003. We then adjust the inputs from Apennine Rivers to better match the sediment loads reported in Cattaneo, et al. [2003]. Input for the Po River was specified using gauged values of freshwater and the rating curve consistent with Syvitski and Kettner [2005]. For the 2002 / 2003 year, using these values gives a sediment input of 15.5 million tons for the Po River, and 32 million tons for the Apennine Rivers, similar to the annual values reported by Cattaneo, et al. [2003].

Because the 2-3 km resolution model developed to study dispersal throughout the Adriatic is incapable of resolving relevant spatial scales on the Po River delta, VIMS has implemented an alternate ROMS model within the Adriatic that better resolves that area. With ~750 m resolution over the Po delta, this model is addressing questions of sediment export and striving to account for the depositional signature created by floods of the Po River.

WORK COMPLETED

Efforts at VIMS from Fall, 2004 – Fall, 2005 have focused on three objectives:

(1) better resolve dispersal and deposition at the Po River delta,

2) evaluate the fluvial input signal and dispersal patterns throughout the Adriatic, and

(3) consider the impact that seafloor sediment availability has on sediment concentrations.

Towards the first objective, a high resolution model of the Po River delta has been developed and used to test hypothesis of dispersal mechanisms operating in that area. Simulations of the 2002 / 2003 time period have been completed, as well as more process-oriented studies of dispersal during Bora and

Siroccos wind conditions. The simulation of 2002 / 2003 is being compared to tripod and seabed data compiled by PASTA co-PIs Traykovski, Wheatcroft, and Nittrouer.

Sediment concentrations and dispersal are sensitive to resuspension of seabed material. Calculations indicated that large scale erosional patterns predicted for the 2002 /2003 time period were sensitive to the initial sediment bed used. Data from PASTA and Italian scientists (Nittrouer and Palinkas, Hill and George, and Cattaneo) were used in an attempt to derive a realistic initial sediment bed for the 2002 / 2003 model simulation. These data points, concentrated in the western Adriatic, were combined with a sediment texture map to estimate initial bed fractions of sand, silt, and clay for model runs (figure 1). Data from other, historical studies, provided by DBSeabed (PIs Jenkins and Syvitski, INSTAAR) were not used for this interpolation, because of perceived inconsistencies in the historical data.

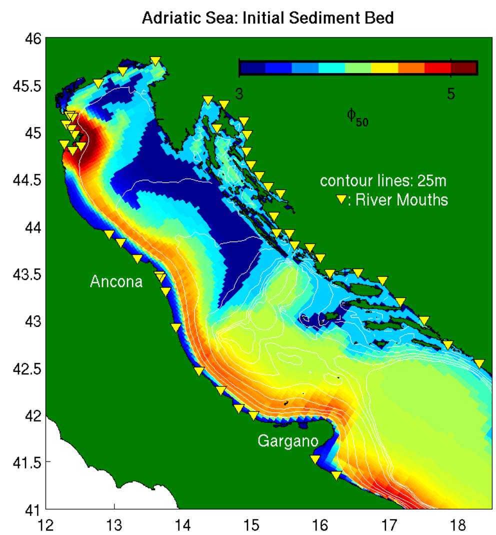

Figure 1: Sediment bed map based on PASTA data and Croatian sediment texture map. Color indicates initial mean grain size in phi units. Bathymetric contours drawn at 25m intervals. Yellow triangles show location of 48 freshwater sources, includin Po distributory mouths, Apennine Rivers, and Dalmatian groundwater.

RESULTS

Numerical modeling of the Adriatic for the 2002 / 2003 time period shows intriguing similarity between predicted deposits and Holocene accumulation patterns. Within the 10 month period modeled, resuspended seabed material dominates the sediment concentrations and net deposited material throughout most of the Adriatic. The exception to this is in the vicinity of the Po River, where newly delivered fluvial sediment dominates the suspended material and the deposition along the subaqueous Po delta. Sediment from the Po River appears to have a fairly long residence time in the northern Adriatic, with the bulk of it (about 95%) remaining north of Ancona during the 10 month simulation (figure 2). Sediment from the Apennine Rivers is predicted to travel further (about 40 km) than Po sediment travels (about 6 km) during the 10 months simulated. Most of the difference in these advection length scales is due to assumptions made about the settling velocities of fluvial material supplied by Po and Apennine Rivers (figure 2). Sediment from the Po is assumed to be packaged as flocculated material, settling at about 1 mm/s, whereas material from the Apennine Rivers is assumed to be delivered as smaller aggregates or single grains, settling at 0.1 mm/s, based on insights from Fox et al. [2004a; 2004b] and Mikkelson et al. [2005].

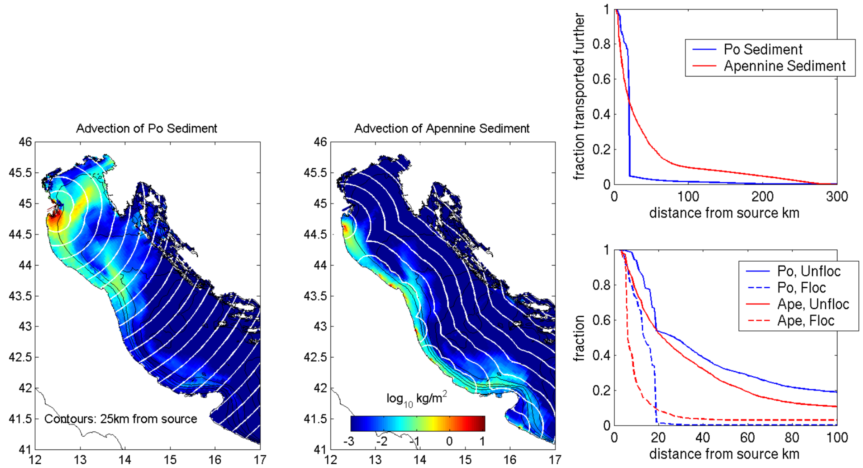

Figure 2: Advection length scales of fluvial sediment. Left panels: white lines- distances from Po and Apennine Rivers. Color represents mass of sediment per m^2. Right panels: Apennine sediment travels further on average than Po Sediment. Most of the difference due to settling velocities assumed.

Four deposits are predicted: the Po delta, offshore of the Po delta, offshore of Ancona, and north of Gargano (figure 3d). Of these, only the deposit offshore of Ancona is not observed. This deposition may be sensitive to the initial sediment bed, and may shrink once a more realistic initial bed is used (figure 1). The deposit offshore of the Po delta lies underneath the counter-clockwise gyre present there during Bora conditions, and mimics the seafloor texture seen in figure 1. Sediment from both the Po and Apennine Rivers contributes to deposition north of the Gargano Peninsula, visible in both Holocene thicknesses [*Cattaneo et al.*, 2003] and our results (figure 3d). Over the timescales of this model run, Apennine Rivers contribute more sediment to the Gargano deposit (~0.1 kg/m^2) than does the Po River (~0.01 kg/m^2; figure 2). Both fluvial sources, however, are dwarfed by material resuspended from the seafloor (compare figure 2 to figure 3d). Efforts to improve the initial seabed used (see figure 1) will refine our resuspension predictions. The location of the Gargano deposit seems to be linked to spatial patterns in wave energy (figure 3b) which are in turn driven by persistent locations of energetic winds during Bora (figure 3a). Because Bora winds are orographically steered by mountain ridges and valleys along the east coast of the Adriatic, the location of energetic storm waves is a robust feature over long timescales. The relative low in wave heights along the north side of the Gargano Peninsula may be related to deposition there. This low in wave energy is due to the fact that the area is sheltered from Sirocco winds that blow from the south, and lies to the south of the energetic Bora wind bands seen in figure 3a.

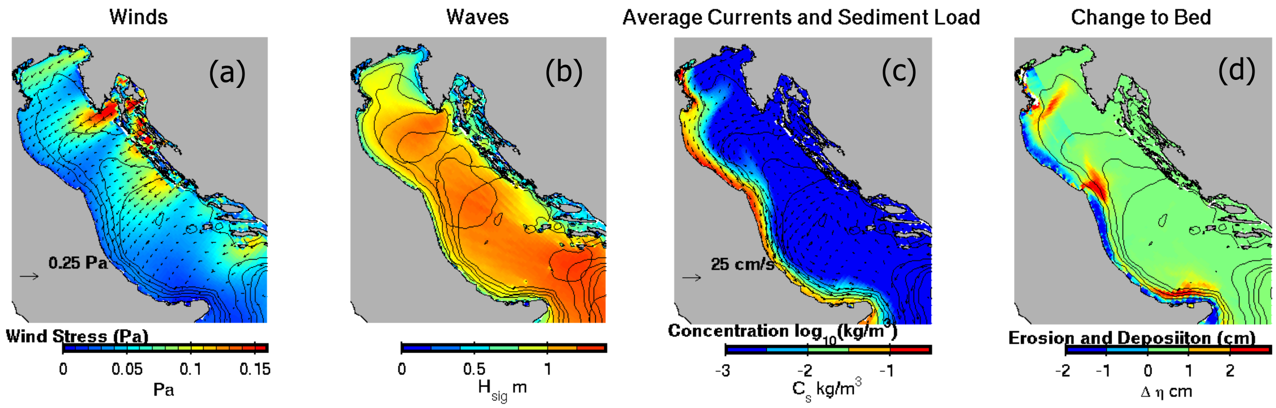

Figure 3: Summary of model calculations for September, 2002 – June, 2003. (a) Time-averaged wind stress from BOLAM model. (b) Time-averaged ave height from SWAN model. Locations where wave height variability is high are outlined. (c) Average currents and sediment concentrations. (d) Net erosion (blue) and deposition (red) predicted.

The Po is the largest supplier of sediment to the Adriatic, and focus on this area has shed some light into depositional processes there. Because of the high settling velocities assumed for sediment from the Po River, much of it settles very close to the five distributary mouths (figure 4). Predicted depositional patterns during the 2002 / 2003 PASTA experiment bear close resemblance to observed deposits from a large flood of the Po River that occurred during the fall of 2000 [figure 4, *Wheatcroft et al.*, 2005a]. Predicted sedimentation patterns during idealized Bora and Sirocco forcing shows that deposition during Bora conditions best matches the deposits observed following large floods of the Po River by Palinkas and Nittrouer [2005] and Wheatcroft et al. [2005a]. Prolonged Sirocco conditions, however, seem to be capable of driving significant sediment export from the Po delta region.

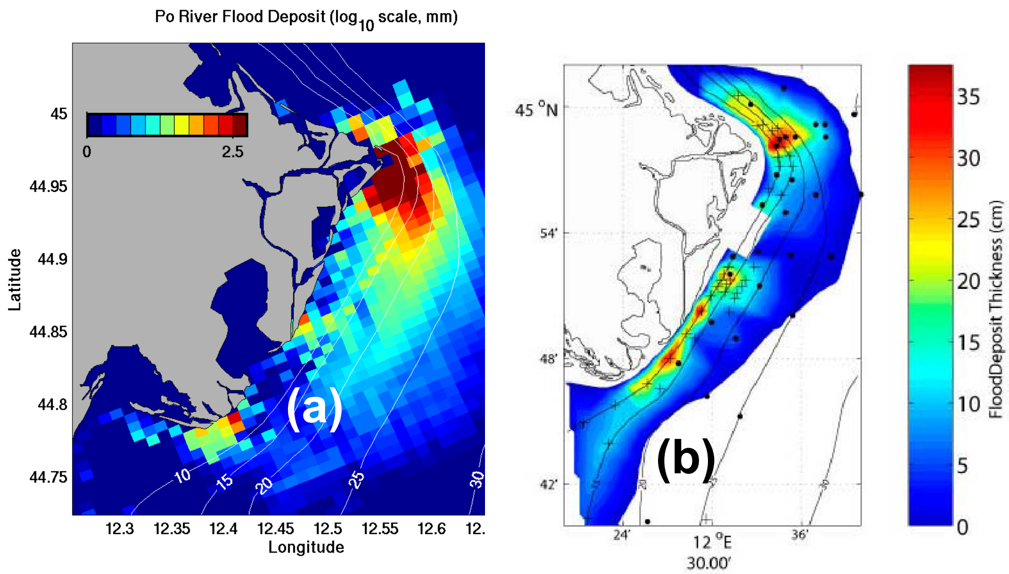

Figure 4: (a) predicted sedimentation during the 2002 / 2003 PASTA experiment. (b) Deposit thicknesses observed by Wheatcroft for the October – December, 2000 flood. Note that (a) uses a logarithmic scale, while (b) uses a linear scale. This was done so that thin layers of sediment could be seen away from the distributary mouths in (a).

IMPACT/APPLICATIONS

Several components of this work are of interest to EuroStrataform and other colleagues. Improved estimates of sediment and freshwater delivery during the 2002 / 2003 fall and winter season will better constrain our estimates of sediment budgets during this time. Our emphasis on the Po delta region promises to bridge a gap between the three dimensional modeling effort and seabed and tripod observations of the Po delta region conducted by researchers at Oregon State, University of Washington, and WHOI. Colleagues are also using the sediment bed map generated (figure 1).

RELATED PROJECTS

This year, methods for predicting sediment dispersal and deposition on the Eel River shelf, northern California were refined. Two mechanisms for sediment transport (dilute suspension and near-bed wave dominated gravity flows) have been identified on this energetic, flood-dominated shelf. We included both of these mechanisms in a three-dimensional sigma-coordinate model [*Harris et al.*, 2004]. Approximately 30% of sediment delivered to the coastal ocean by floods of the Eel River is retained in mid-shelf muds and inner shelf sands [*Crockett and Nittrouer*, 2004; *Sommerfield and Nittrouer*, 1999; *Wheatcroft and Borgeld*, 2000]. Using our three-dimensional model, we conclude that about 20% of the sediment delivered is transported north of the shelf by wind-forced ocean currents, and the remaining sediment is spread as a thin, widely-dispersed drape [*Harris et al.*, 2005]. The cross-shelf location of a flood deposit is sensitive to wave energy, but the volume of the flood deposit depends critically on partitioning of sediment into aggregated particles and disaggregated single grains[*Harris et al.*, 2005]. Related to this study, I have contributed towards two chapters of a volume on continental-margin sedimentation [*Syvitski et al.*, 2005; *Wheatcroft et al.*, 2005b].

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